

Arctic Oscillation and Polar Vortex Analysis and Forecasts

March 22, 2021

Special blog on winter 2018/2019 retrospective can be found here
- <http://www.aer.com/winter2019>

Special blog on winter 2017/2018 retrospective can be found here
- <http://www.aer.com/winter2018>

Special blog on winter 2016/2017 retrospective can be found here
- <http://www.aer.com/winter2017>

Special blog on winter 2015/2016 retrospective can be found here
- <http://www.aer.com/winter2016>

Dr. Judah Cohen from Atmospheric and Environmental Research (AER) embarked on an experimental process of regular research, review, and analysis of the Arctic Oscillation (AO) and Polar Vortex (PV). This analysis is intended to provide researchers and practitioners real-time insights on one of North America's and Europe's leading drivers for extreme and persistent temperature patterns.

During the winter schedule the blog is updated once every week. Snow accumulation forecasts replace precipitation forecasts. Also, there is renewed emphasis on ice and snow boundary conditions and their influence on hemispheric weather. With the start of spring we transition to a spring/summer schedule, which is once every two weeks. Snow accumulation forecasts will be replaced by precipitation forecasts. Also, there will be less emphasis on ice and snow boundary conditions and their influence on hemispheric weather.

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The AO/PV blog is partially supported by NSF grant AGS: 1657748.

Summary

- The Arctic Oscillation (AO) is currently positive and is predicted to remain neutral to positive the next two weeks as pressure/geopotential height anomalies are predicted to remain mostly negative across the Arctic with mixed pressure/geopotential height anomalies across the mid-latitudes. The North Atlantic Oscillation (NAO) is also predicted to remain neutral to positive the next

two weeks as persistent negative pressure/geopotential height anomalies are predicted across Greenland and Iceland.

- This week ridging/positive geopotential height anomalies previously centered over the United Kingdom (UK) are predicted to overspread across much of Europe this week, bringing with it normal to above normal temperatures with the exception of Southeastern Europe where troughing will linger the longest. However, in early April the ridging/positive geopotential height anomalies are predicted to become centered in the North Atlantic allowing some cooler temperatures to filter into Eastern Europe from Western Russia.
- Ridging/positive geopotential height anomalies coupled with normal to above normal temperatures are predicted to continue across Southern and Eastern Asia while troughing/negative geopotential height anomalies coupled with normal to below temperatures will persist across Northern and Western Asia this week but Northern and Central Asia next week.
- The general pattern across North America continues to be troughing/negative geopotential height anomalies coupled with normal to below temperatures across Alaska, Western Canada and the Western United States (US) while ridging/positive geopotential height anomalies are predicted coupled with normal to above normal temperatures, across Eastern Canada and the Eastern US. One exception will be next week when troughing and cooler temperatures extend into eastern North America associated with a minor stratospheric polar vortex (PV) stretching event.
- In the Impacts section I discuss the influence of the strong polar vortex (PV) on the weather across the Northern Hemisphere (NH) but also a relatively minor PV disruption this week.

Impacts

I do want to let everyone know that this is the last blog in the winter season format. There will be no blog next week and then in two weeks the blog will resume in its summer format and will be published once every two weeks.

I also want to point out that we have updated and improved the CFS temperature forecasts (**Figure 15**), which will hopefully resolve the cold bias for Eurasia and the warm bias for North America in our plots.

The theme from last week of a positive AO, a strong stratospheric PV and cold/negative polar cap geopotential height anomalies (PCHs) for the foreseeable future continues. All these favor relatively mild temperatures for the Eastern US, Europe and East Asia. But there are some exceptions. What seems like an almost rogue high pressure/ridging across Greenland last week, is making its way east this week. High pressure across Greenland favors troughing across Europe and that brought with it a period of relatively cold temperatures. But as the high pressure/ridging spreads across Europe, temperatures are predicted to turn relatively warm over the next two weeks.

The other exception can really be described as a respite next week from an extended period of well above normal temperatures in the Eastern US. I have been anticipating a minor PV disruption where the PV stretches, and it does look like it is finally going to happen this week with the impacts being felt next week. I include in **Figure i**, the latest PV animation that shows for this week ridging building near the Dateline this week that helps to stretch the PV and extends the colder geopotential heights associated with the PV into Canada. These events tend to bring colder temperatures to the Eastern US and East Asia. But this event looks to be a relatively minor even for these normally minor events. But also given the lateness of the season (increasing solar radiation) and lack of snow in the US, it does seem that its impacts will be to a large part blunted. Also, you can see from the animation the PV returns next week to a more circular shape with relatively low heights centered in the Arctic. These are the characteristics of a strong PV that favors relatively mild temperatures across the mid-latitudes.

Initialized 00Z 10 hPa HGT/HGTa 22-Mar-2021

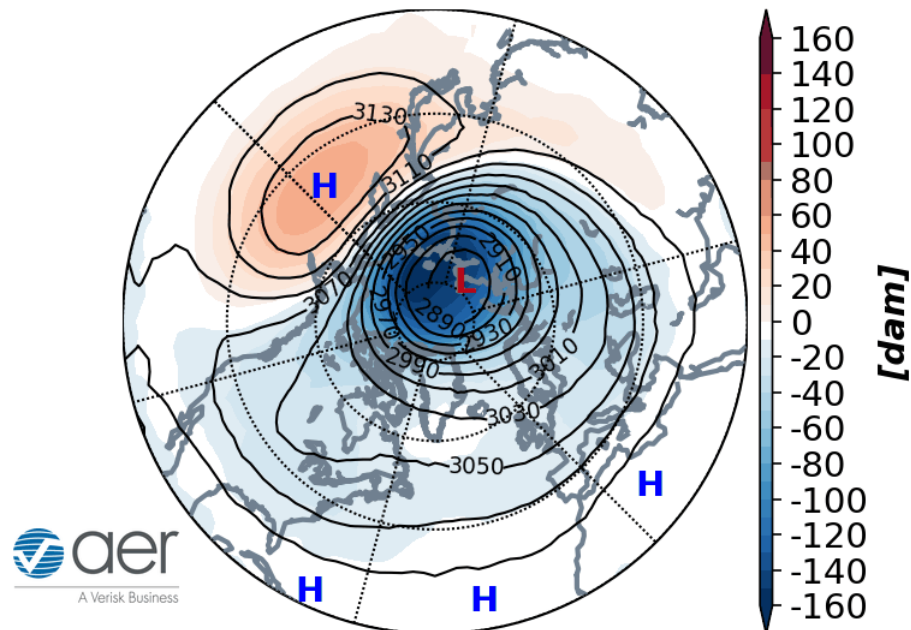


Figure i. Observed and predicted daily geopotential heights (dam; contours) and anomalies (shading) through April 6, 2021. The forecast is from the 00Z 22 March 2021 GFS ensemble.

Just quickly looking towards the spring season, in recent springs, the warmth has been especially aggressive across Eurasia and less so across North America. However, this spring may diverge from these recent trends. There is a healthy snow cover across northern Eurasia and Arctic sea ice is more extensive than recent years. Therefore, the

relatively extensive snow cover and sea ice in the Eurasian sector could hold back the heat in the short term but probably not in the long term. In contrast, North American snow cover is sparser relative to recent years and could help accelerate the spring warm-up. Warming temperatures will be abetted by the strong PV but could reverse if a dynamic final warming of the PV occurs as happened last spring.

1-5 day

The AO is predicted to remain positive to possibly strongly positive this week (**Figure 1**) as negative geopotential height anomalies dominate the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 2**). And with negative geopotential height anomalies predicted across Greenland (**Figure 2**), the NAO is predicted to remain positive as well.

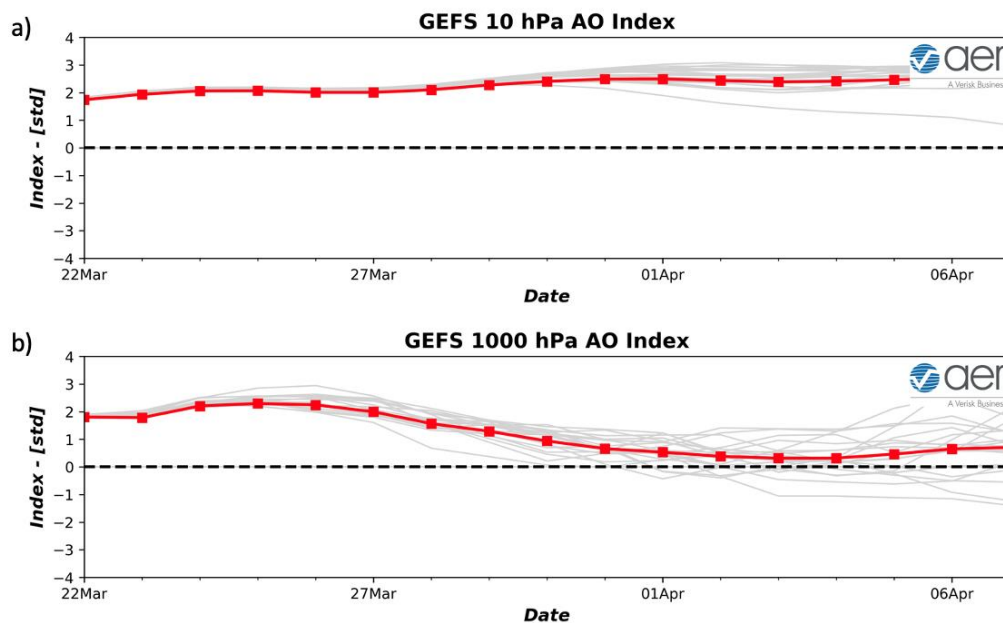


Figure 1. (a) The predicted daily-mean AO at 10 hPa from the 00Z 22 March 2021 GFS ensemble. **(b)** The predicted daily-mean near-surface AO from the 00Z 22 March 2021 GFS ensemble. Gray lines indicate the AO index from each individual ensemble member, with the ensemble-mean AO index given by the red line with squares.

Ridging/positive geopotential height anomalies previously centered across the UK are predicted to spread across much of Europe this week (**Figures 2**). **This will favor** normal to below normal temperatures across much of Europe though one exception will be Southeastern Europe **with** normal to below normal temperatures due to lingering troughing across the region (**Figure 3**). Persistent troughing/negative geopotential height anomalies across Northern and Western Asia are predicted to continue for one more week with ridging/positive geopotential height anomalies across

Southern and Eastern Asia (**Figure 2**). This is predicted to favor normal to below normal temperatures across far Northern and Eastern Siberia and parts of western Asia with normal to above normal temperatures widespread across the remainder of Asia (**Figure 3**).

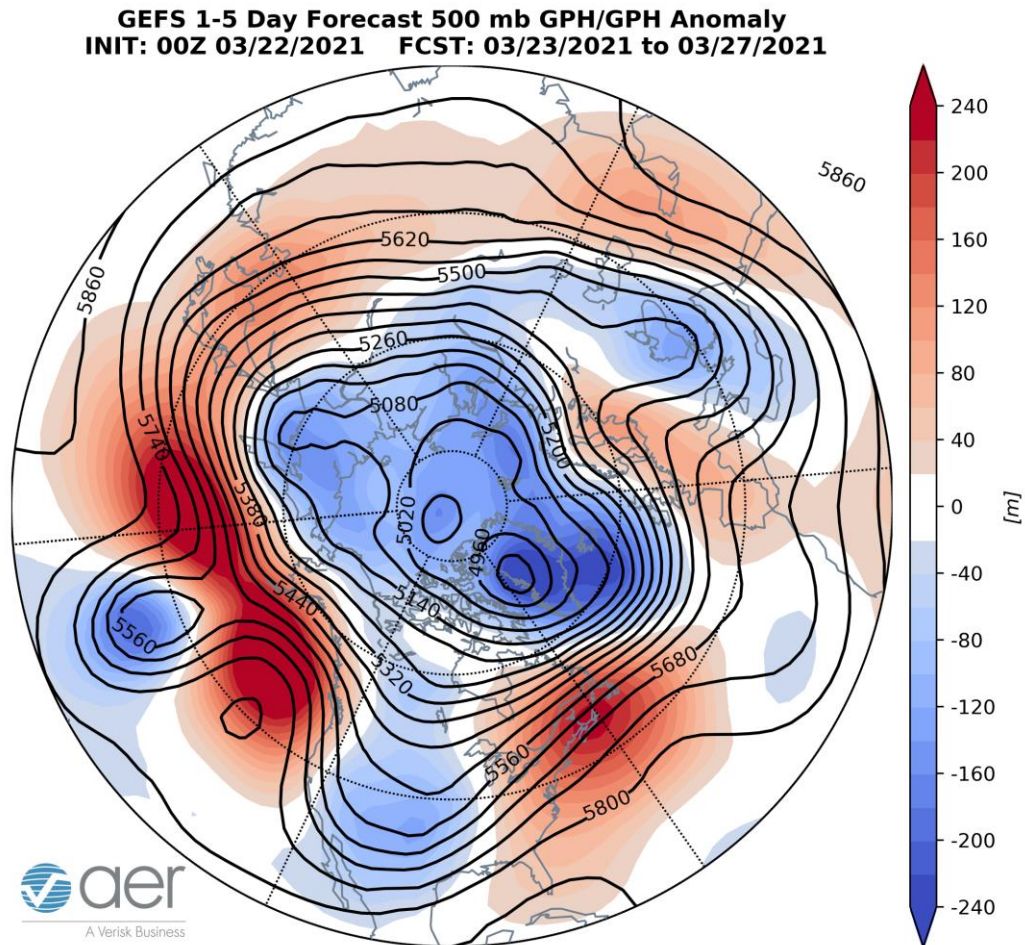


Figure 2. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 23 – 27 March 2021. The forecasts are from the 00z 22 March 2021 GFS ensemble.

This week, ridging/positive geopotential height anomalies in the Gulf of Alaska and in eastern North America will anchor troughing/negative geopotential height anomalies in western North America this period (**Figure 2**). This pattern is predicted to bring normal to below normal temperatures across Alaska, Northern and Western Canada and the Western US with normal to above normal temperatures across Southeastern Canada and the Eastern US (**Figure 3**).

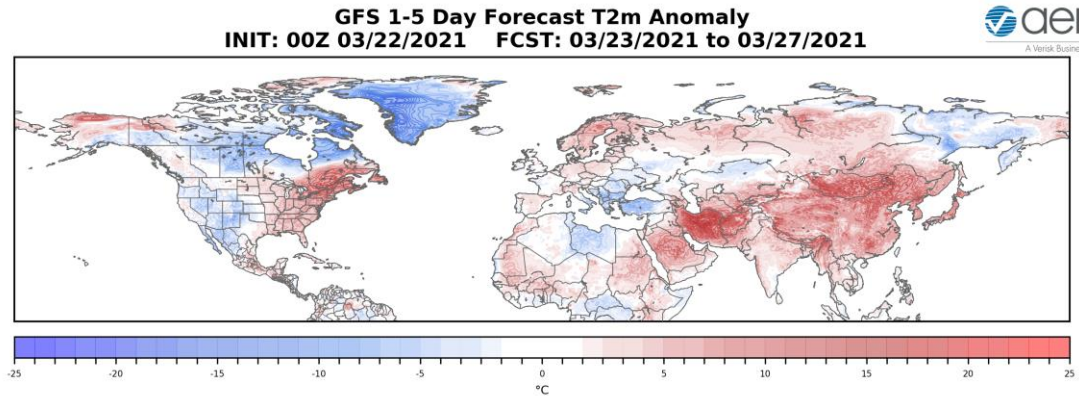


Figure 3. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 23 – 27 March 2021. The forecast is from the 00Z 22 March 2021 GFS ensemble.

Trouching and/or colder temperatures are predicted to support regional snowfall across Turkey, the Himalayas, Eastern Siberia, Western Alaska and Eastern Canada (**Figure 4**) while warmer temperatures will cause widespread snow melt in Europe, Asia, Western Canada and the Western US (**Figure 4**).

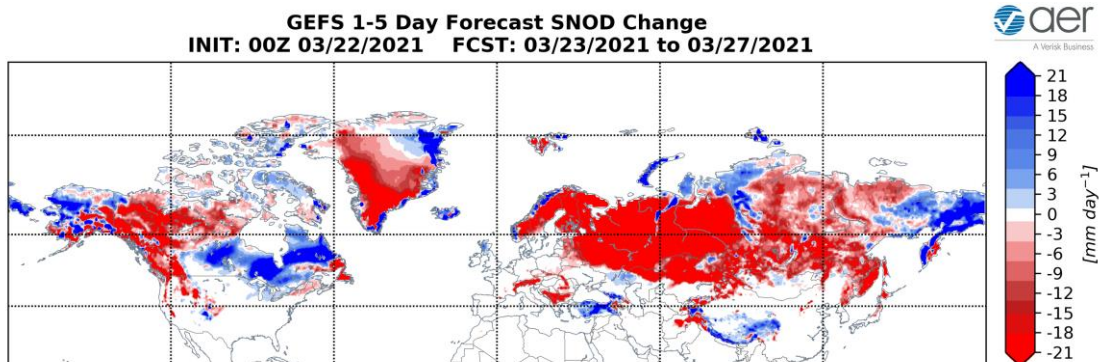


Figure 4. Forecasted snow depth changes (mm/day; shading) from 23 – 27 March 2021. The forecast is from the 00Z 22 March 2021 GFS ensemble.

Mid-Term

6-10 day

The AO is predicted to remain positive next week (**Figure 1**) as negative geopotential height anomalies continue to dominate the Arctic with mixed geopotential height anomalies across the mid-latitudes of the NH (**Figure 5**). And with negative geopotential height anomalies predicted across Greenland (**Figure 5**), the NAO is predicted to remain positive as well.

GEFS 6-10 Day Forecast 500 mb GPH/GPH Anomaly
INIT: 00Z 03/22/2021 FCST: 03/28/2021 to 04/01/2021

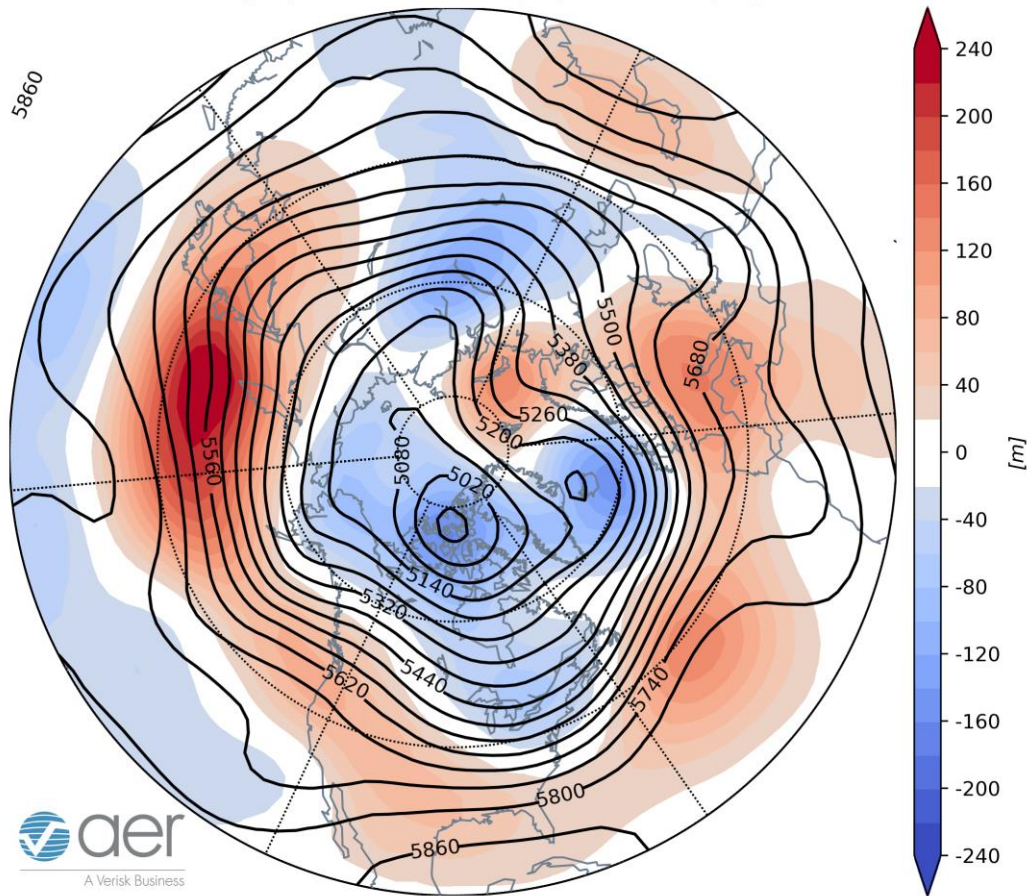


Figure 5. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 28 March – 1 April 2021. The forecasts are from the 00z 22 March 2021 GFS ensemble.

Ridging/positive geopotential height anomalies are predicted to continue to build across all of Europe next week (**Figure 5**). This will favor normal to above normal temperatures across all of Europe including the UK (**Figure 6**). Troughing/negative geopotential height anomalies will persist across Northern Asia but will also move from Western Asia into Central Asia with ridging/positive geopotential height anomalies across Southern and Eastern Asia (**Figure 5**). This pattern favors normal to below normal temperatures across much of Central Asia and Eastern Siberia with normal to above normal temperatures widespread across Southern and Eastern Asia (**Figure 6**).

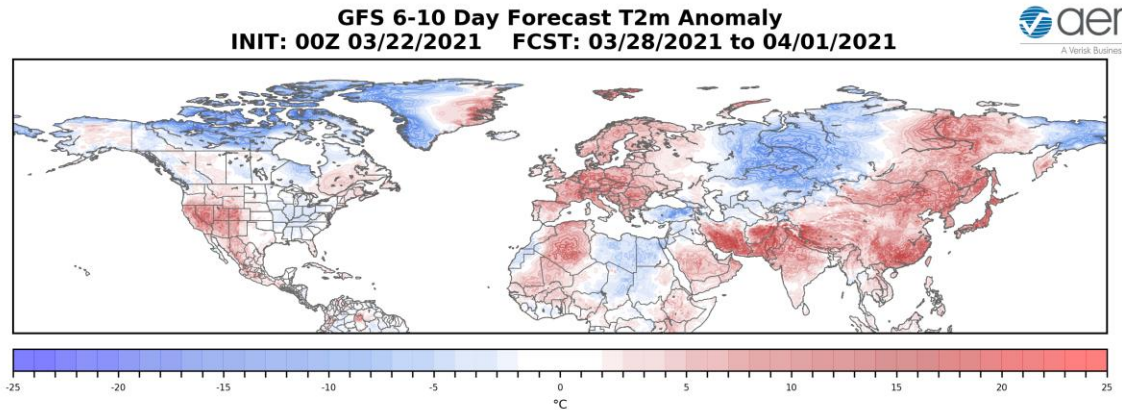


Figure 6. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 28 March – 1 April 2021. The forecasts are from the 00Z 22 March 2021 GFS ensemble.

Trouching/negative geopotential height anomalies are predicted to briefly slide into Eastern Canada and the Northeastern US associated with a PV stretching event with ridging/positive geopotential height anomalies across Western Canada and the Southern and Western US this period (**Figure 5**). This pattern is predicted to bring normal to below normal temperatures across Northern and Eastern Canada and the Eastern US with normal to above normal temperatures across Alaska, Western Canada and the Western US (**Figure 6**).

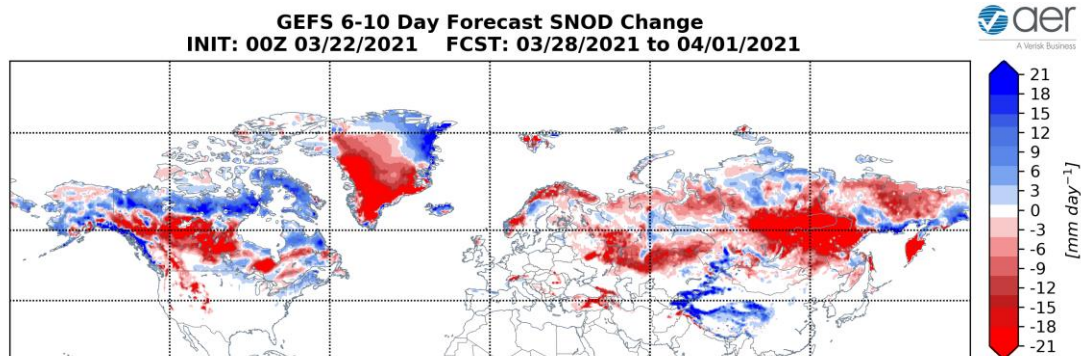


Figure 7. Forecasted snow depth changes (mm/day ; shading) from 28 March – 1 April 2021. The forecasts are from the 00Z 22 March 2021 GFS ensemble.

Trouching and/or colder temperatures are predicted to support regional snowfall across the higher elevations of Central Asia, Northern and Eastern Canada and possibly New England (**Figure 7**) while warmer temperatures will cause widespread snow melt in Europe, Asia, Central Canada and the Western US (**Figure 7**).

11-15 day

As geopotential height anomalies are predicted to remain negative for much of the Arctic with mixed positive geopotential height anomalies across the mid-latitudes of the NH (**Figure 8**), the AO should remain positive this period (**Figure 1**). With negative pressure/geopotential height anomalies spread across Greenland (**Figure 8**), the NAO is predicted to remain positive this period as well.

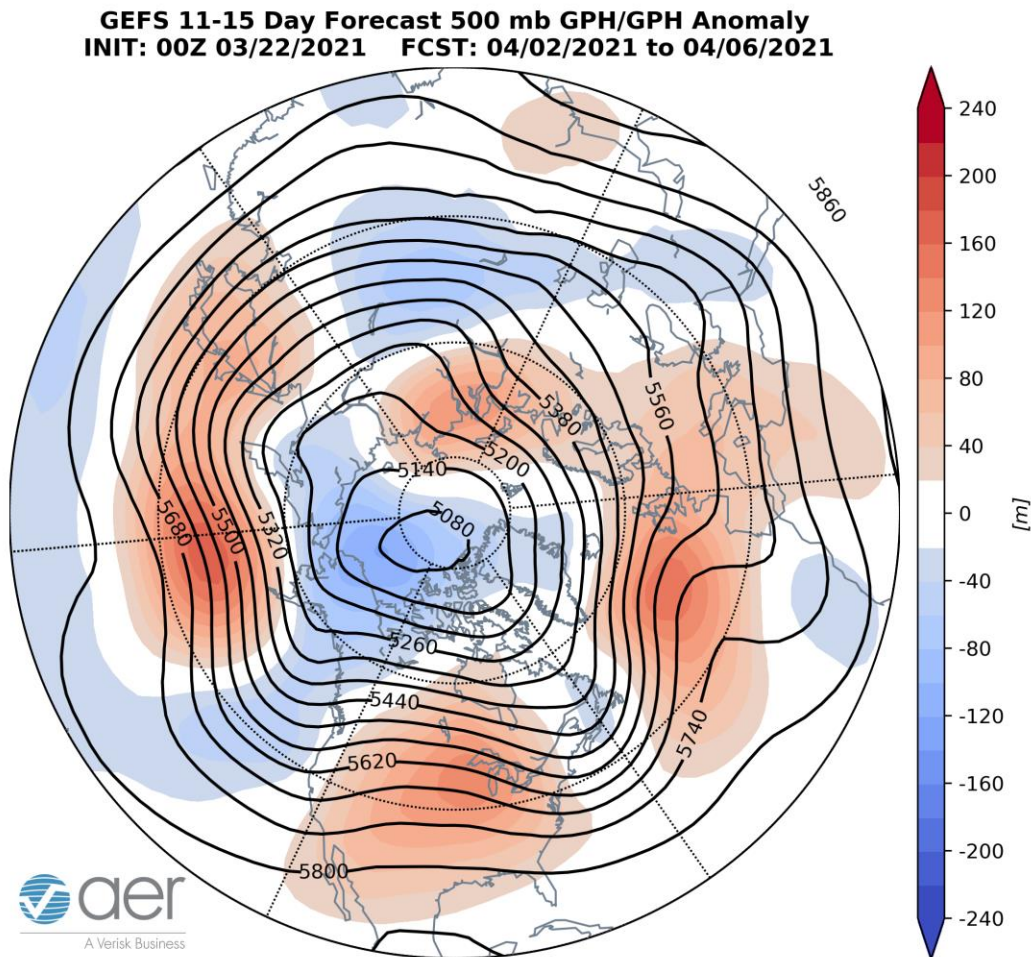


Figure 8. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere from 2 – 6 April 2021. The forecasts are from the 00z 22 March 2021 GFS ensemble.

Ridging/positive geopotential height anomalies previously centered over Europe are predicted to become centered in the eastern North Atlantic instead this period (**Figure 8**). Persistent relatively high heights continue to favor widespread normal to above normal temperatures across Europe including the UK, however some cooler air is predicted to filter from Western Russia into Eastern Europe (**Figures 9**).

Trouching/negative geopotential height anomalies are predicted to persist across Northeastern Asia, but ridging/positive geopotential height anomalies are predicted to build across the Urals and Barents-Kara Seas forcing trouching/negative geopotential

height anomalies in Central Asia (**Figure 8**). This pattern favors normal to below normal temperatures across Northeastern and Central Asia with normal to above normal temperatures across the Urals, Western Siberia and Southern Asia (**Figure 9**).

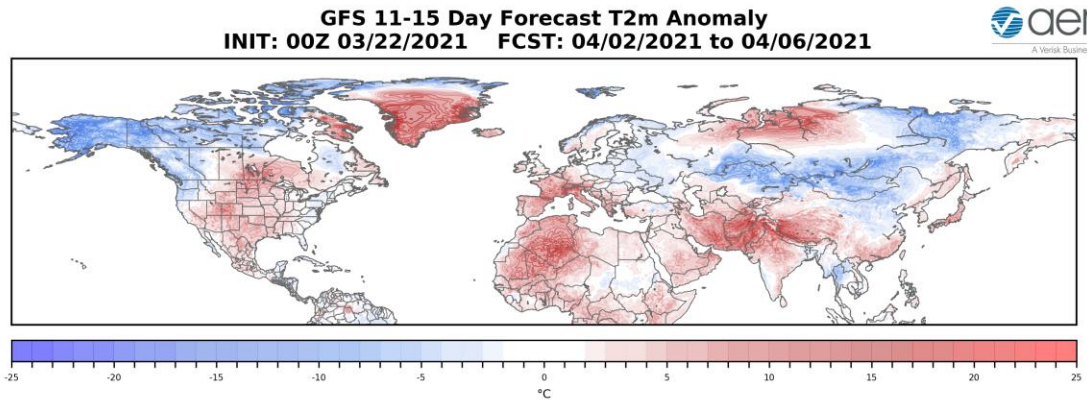


Figure 9. Forecasted surface temperature anomalies ($^{\circ}\text{C}$; shading) from 2 – 6 April 2021. The forecasts are from the 00z 22 March 2021 GFS ensemble.

Trounging/negative geopotential height anomalies are predicted to return to western North America with building ridging/positive geopotential height anomalies in central and eastern North America this period (**Figure 8**). This pattern favors normal to below normal temperatures for Alaska, Northern and Western Canada and the Northwestern US with normal to above normal temperatures across the Eastern Canada and the Central and Southern US (**Figure 9**).

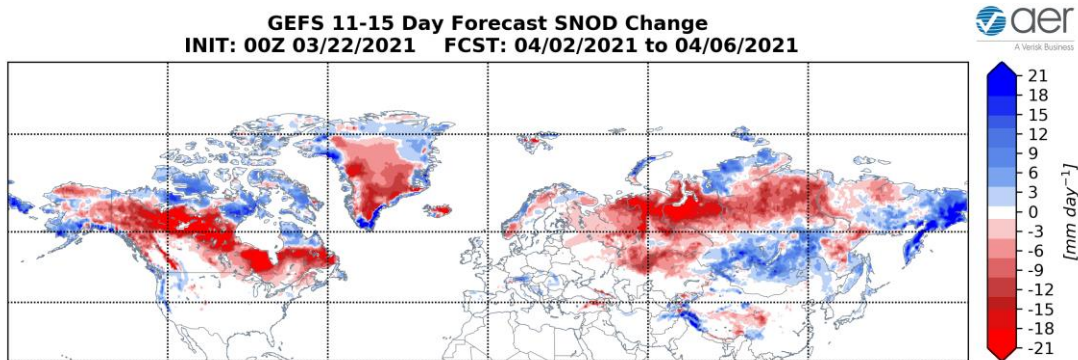


Figure 10. Forecasted snow depth changes (mm/day; shading) from 2 – 6 April 2021. The forecasts are from the 00z 22 March 2021 GFS ensemble.

Trounging and/or colder temperatures are predicted to support regional snowfall across Central Asia, Northern Canada and the higher elevations along the US West Coast (**Figure 10**) while warmer temperatures will cause widespread snow melt in Europe, Asia and Canada (**Figure 7**).

Longer Term

30-day

The latest plot of the polar cap geopotential height anomalies (PCHs) currently shows normal to cold/negative PCHs throughout the troposphere and stratosphere for the next two weeks (**Figure 11**). The one exception is above normal/warm PCHs in the lower troposphere in early April. The deeper cold/negative PCHs currently in the upper stratosphere are predicted to descend through the stratosphere and troposphere all the way to the surface this week (**Figure 11**) contributing to a spike in the surface AO (**Figure 1**).

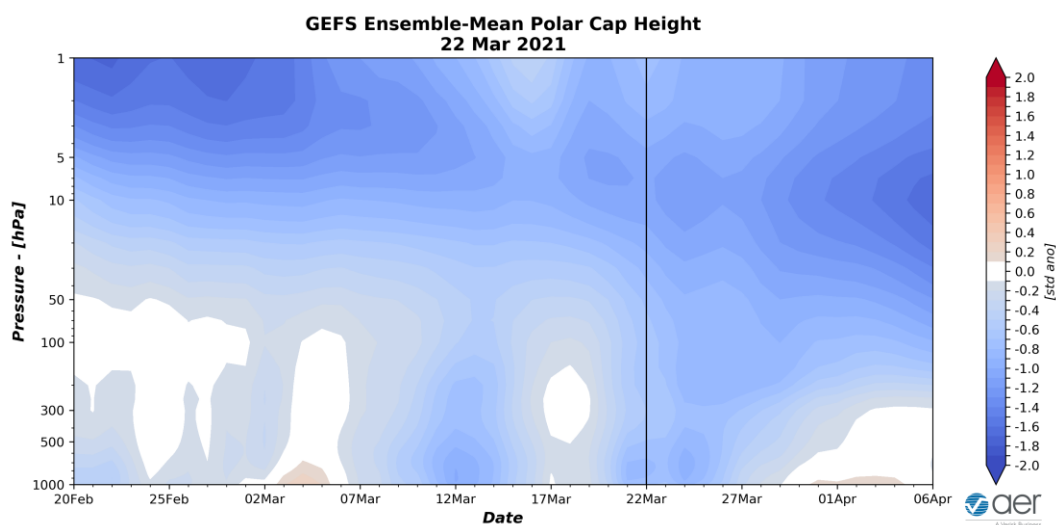


Figure 11. Observed and predicted daily polar cap height (i.e., area-averaged geopotential heights poleward of 60°N) standardized anomalies. The forecast is from the 00Z 22 March 2021 GFS ensemble.

The overall cold/negative PCHs in the lower troposphere are consistent with the predicted positive surface AO the next two weeks (**Figure 1**). Similarly, the cold/negative PCHs in the mid-stratosphere are consistent with the positive to strongly positive stratospheric AO (at 10 hPa) the next two weeks (**Figure 1**). The return of closer to normal PCHs in the lower troposphere in early April is likely forcing a more neutral surface AO in early April (**Figure 1**).

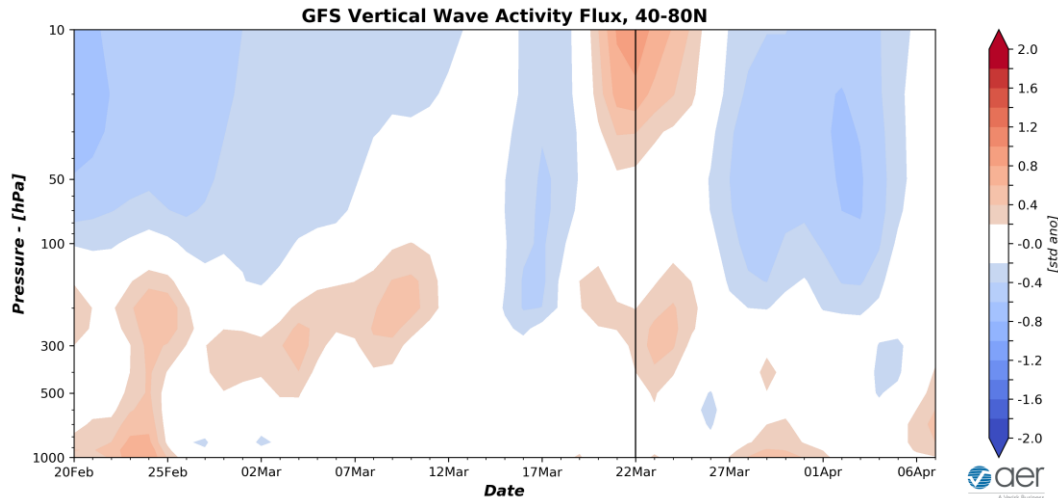


Figure 12. Observed and predicted daily vertical component of the wave activity flux (WAFz) standardized anomalies, averaged poleward of 40-80°N. The forecast is from the 00Z 22 March 2021 GFS ensemble.

The plot of the Wave Activity Flux (WAFz and is proportional to poleward heat transport) forecast is showing currently above normal WAFz especially in the stratosphere (**Figure 12**). The WAFz forecast is predicted to quickly turn negative the remainder of the week. It looks to me that this new pulse is contributing to high pressure near the Dateline this week forcing a minor disruption of the PV with it being stretched.

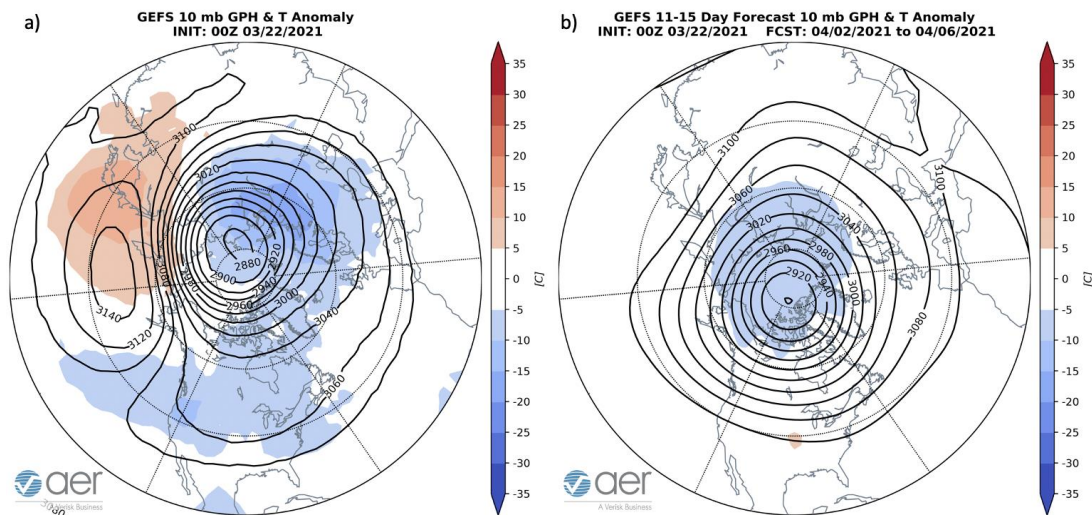


Figure 13. (a) Observed 10 mb geopotential heights (dam; contours) and temperature anomalies (°C; shading) across the Northern Hemisphere for 22 March 2021. (b) Same as (a) except forecasted averaged from 2 – 6 April 2021. The forecasts are from the 00Z 22 March 2021 GFS model ensemble.

The PV continues to remain relatively strong with the vortex centered over the North Slope of Siberia (**Figure 13**). The PV is starting to become elongated from Siberia to western North America (**Figure 13**). I believe that the elongated or stretched PV center may be a sign of a minor PV disruption that favors cold temperatures in East Asia and North America east of the Rockies. However, the shortness in duration of the event and the lateness in the season will limit its impact on the weather. The PV center is then predicted to migrate closer to the North Pole and become circular in shape a sign of the PV quickly recovering from the minor disruption (**Figure 13**).

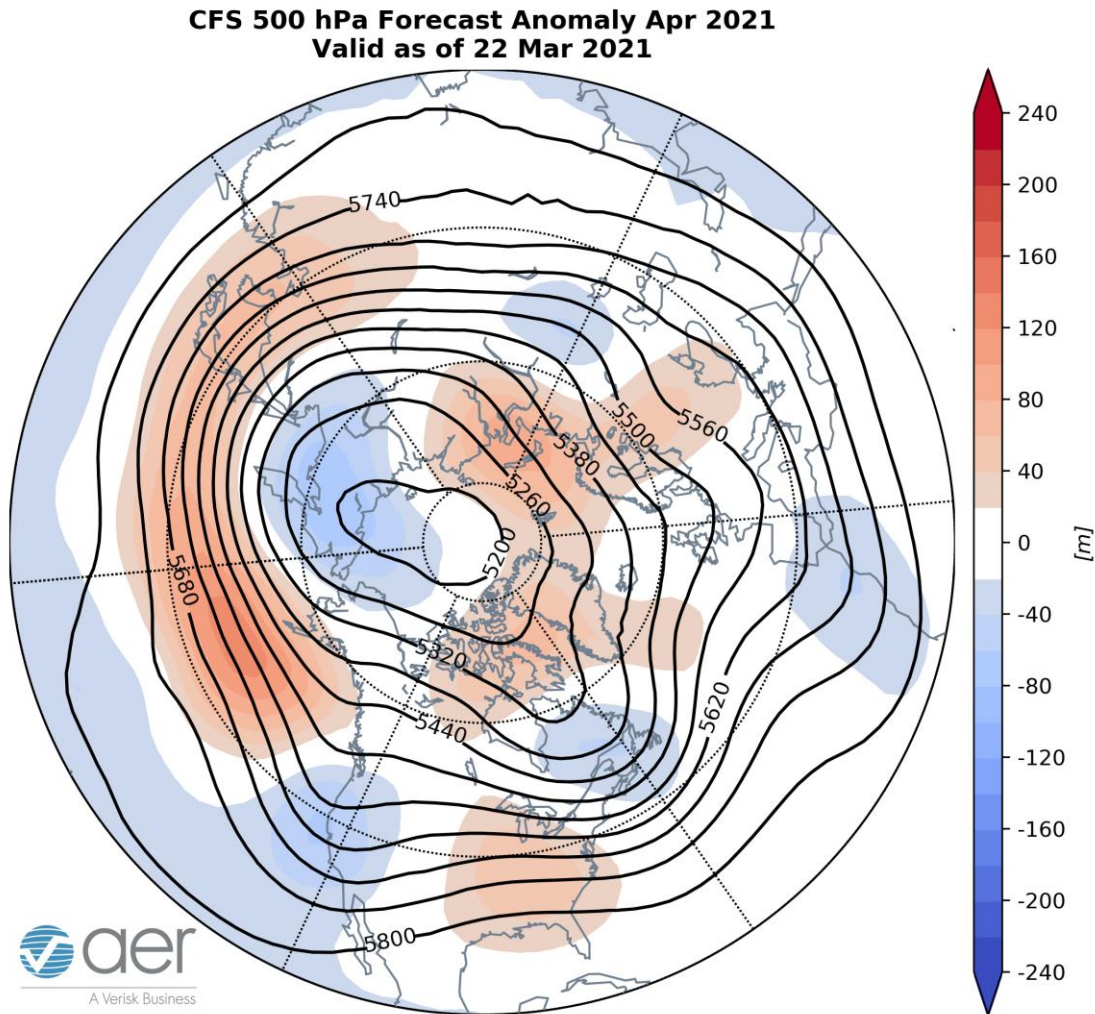


Figure 14. Forecasted average 500 mb geopotential heights (dam; contours) and geopotential height anomalies (m; shading) across the Northern Hemisphere for April 2021. The forecasts are from the 00Z 22 March 2021 CFS.

I include in this week's blog the monthly 500 hPa geopotential heights (**Figure 14**) and the surface temperatures (**Figure 15**) forecast for April from the Climate Forecast System (CFS; the plots represent yesterday's four ensemble members). The forecast

for the troposphere is ridging across Eastern Europe, the Barents-Kara Seas, south of the Aleutians and the Eastern US with troughing in Western Europe, East Asia, Gulf of Alaska, western North America and the Canadian Maritimes (**Figure 14**). This pattern favors relatively cool temperatures for Western Europe, Central and East Asia, Western Canada and the Western US with seasonable to relatively warm temperatures for Eastern Europe, Southern Asia and much of Northern and Eastern Canada and the Eastern US (**Figure 15**).

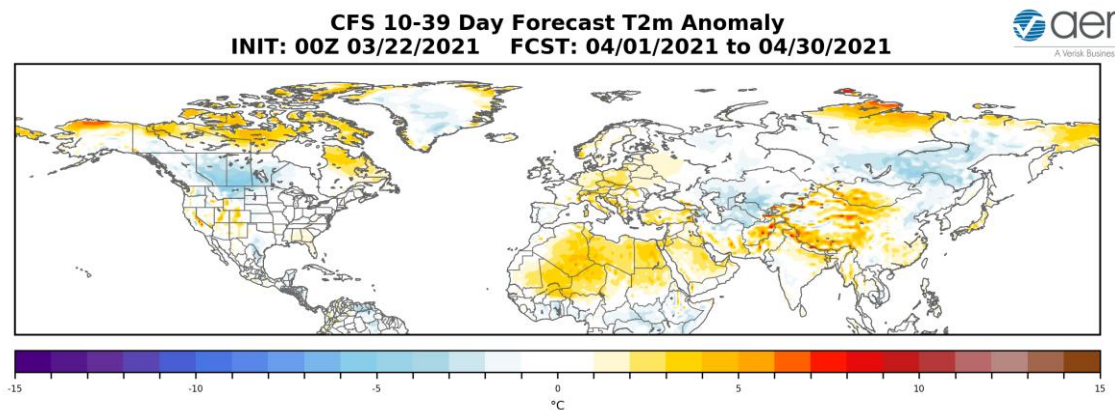


Figure 15. Forecasted average surface temperature anomalies ($^{\circ}\text{C}$; shading) across the Northern Hemisphere for April 2021. The forecasts are from the 00Z 22 March 2021 CFS.

Surface Boundary Conditions

Arctic sea ice extent

Arctic sea ice is likely near its seasonal maximum and remains below normal but more extensive than recent winters. Negative sea ice anomalies exist mostly in the Barents Sea, Baffin Bay and the Bering Sea (**Figure 16**).

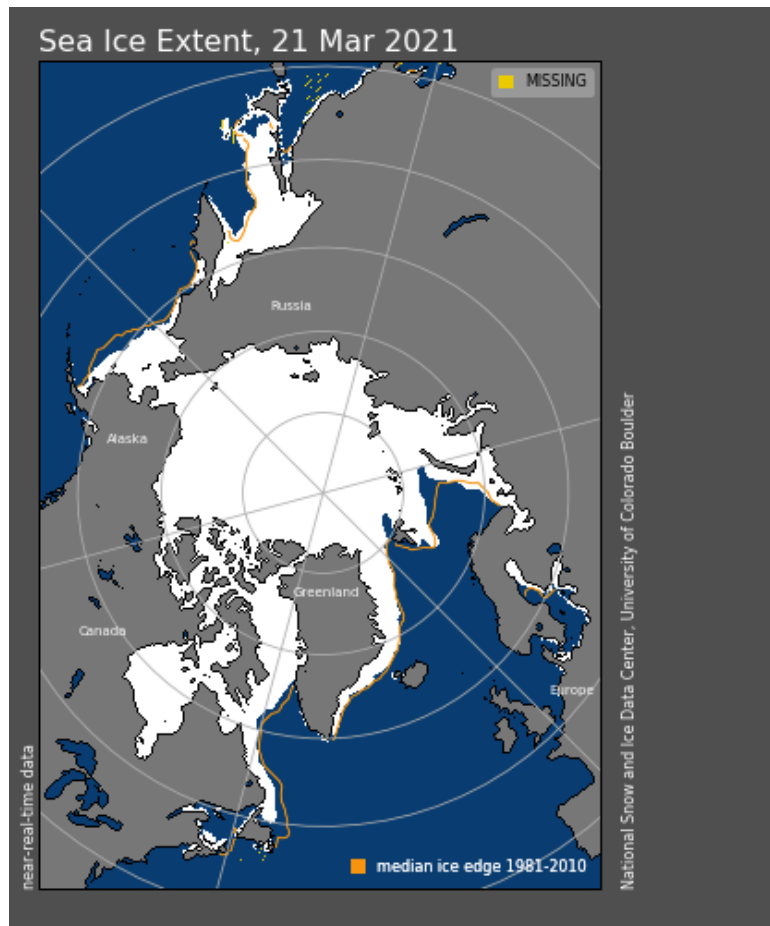


Figure 16. Observed Arctic sea ice extent on 21 March 2021 (white). Orange line shows climatological extent of sea ice based on the years 1981-2010. Image courtesy of National Snow and Ice Data Center (NSIDC).

SSTs/El Niño/Southern Oscillation

Equatorial Pacific sea surface temperatures (SSTs) anomalies remain negative and we continue to observe a weak La Niña conditions (**Figure 17**) and La Niña is expected to persist and remain weak through the spring. Observed SSTs across the NH remain well above normal especially near Alaska and in the Gulf of Alaska, the western North Pacific and offshore of eastern North America though below normal SSTs exist regionally especially in the Southern Hemisphere and south of Iceland. Warm SSTs in the Gulf of Alaska may favor mid-tropospheric ridging in the region.

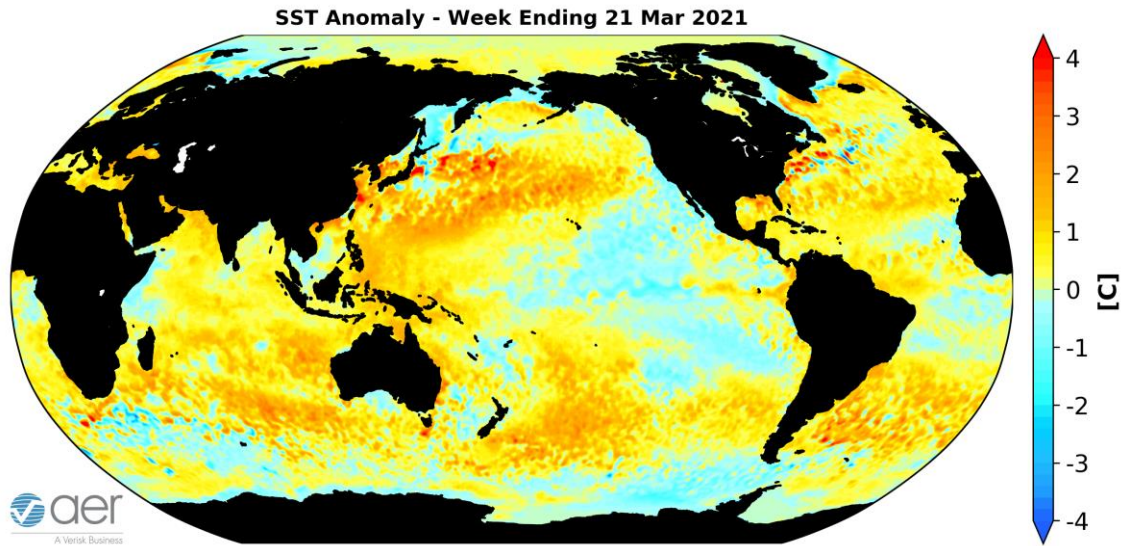


Figure 17. The latest weekly-mean global SST anomalies (ending 21 March 2021). Data from NOAA OI High-Resolution dataset.

Currently no phase of the Madden Julian Oscillation (MJO) is favored (**Figure 18**). The forecasts are for the NJO to remain weak where no phase is favored. The MJO does not seem to be contributing much to the predicted weather pattern across North America but admittedly this is outside of my expertise.

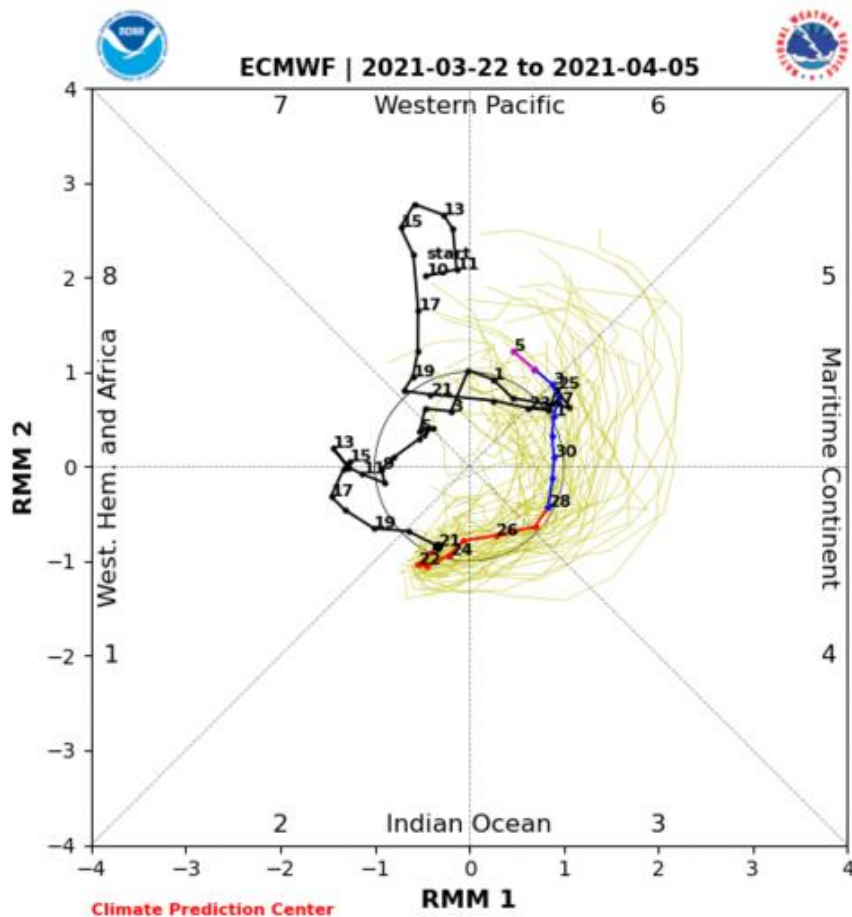


Figure 18. Past and forecast values of the MJO index. Forecast values from the 00Z 22 March 2021 ECMWF model. Yellow lines indicate individual ensemble-member forecasts, with the green line showing the ensemble-mean. A measure of the model “spread” is denoted by the gray shading. Sector numbers indicate the phase of the MJO, with geographical labels indicating where anomalous convection occurs during that phase. Image

source: <http://www.atmos.albany.edu/facstaff/roundy/waves/phasediags.html>

Northern Hemisphere Snow Cover

Snow cover extent decline slowed over the past week across Eurasia and has moved up to near decadal means. Still snow cover extent is in its seasonal decline.

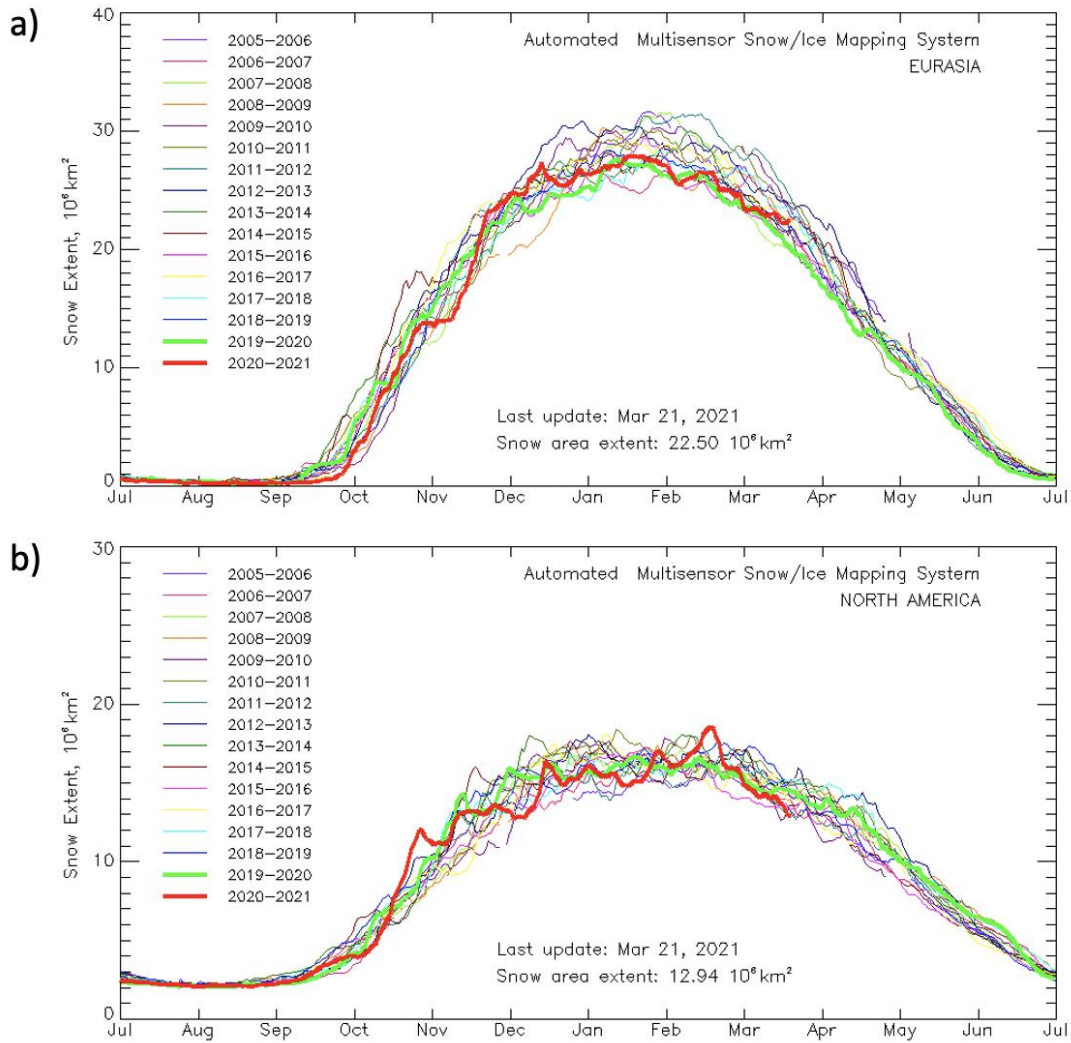


Figure 19. Observed Eurasian (top) and North American (bottom) snow cover extent through 21 March 2021. Image source:

https://www.star.nesdis.noaa.gov/smcd/emb/snow/HTML/snow_extent_plots.html

North American snow cover decline accelerated this past week and remains at decadal lows. Snow cover is in it's seasonal decline.